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Title: Method for manufacturing an organic electroluminescent display device, substrate to be used with such a method and an organic electroluminescent display device obtained with the method.

The invention relates to a method for manufacturing an organic electroluminescent display device, wherein an arrangement of layers is applied to a substrate, such that, in a first direction, conductors extend, as well as second conductors in a second direction, while between crossings of the first and second conductors, an organic electroluminescent compound is provided which emits light under the influence of a voltage.

The invention also relates to a substrate suitable and intended for use in a method according to the invention for manufacturing an organic electroluminescent display device, the method comprising the step of applying a first conductive layer by means of a layer application process.

With the known method for manufacturing an organic electroluminescent display device, the starting point is a substrate manufactured from glass, onto which a structure has been applied with the aid of a photoresist, provided, for instance, through spin coating, which photoresist has been locally exposed and thereupon has been locally removed with washing techniques. These processes are laborious, cost much time and hence are costly. As, in the manufacture of displays, it is the very cost price which plays a predominant part, the provision of a display device wherein such "wet" chemical steps for manufacturing the display device are omitted would be of great advantage.

To this end, according to the invention, the method of the type described in the opening paragraph is characterized in that the substrate is manufactured from plastic and has a surface structure which forms a boundary, at least for a number of the layers which are applied, a first conductive layer being applied by means of a layer application process, the surface structure of plastic substrate being provided with a shadowing

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structure which is such that with the layer application process, parts of this shadowing structure are hardly covered, if at all, with the respective conductive layer, the shadowing structure being such that the electrical resistance prevailing there is great relative to the resistance in the rest of the conductive layer.

Such a plastic substrate which is provided with a surface structure can be manufactured with a plastic formation process known per se such as, for instance, injection molding, embossing, photopolymeric replication or the like. Embossing has been described in, for instance, US-A-4 659 407, photopolymeric replication has been described in WO 87/02934. From, for instance, the manufacture of CDs, injection molding techniques are known with the aid of which very fine submicronstructures can be manufactured in a plastic substrate at relatively very low cost prices. The need of using wet chemical techniques for forming the substrate is thereby cancelled with all associated advantages. Such fine surface structures can also be applied on a film, as is described in, for instance, WO 99/12160 or EP-A-0 408 283.

According to a further elaboration of the invention, the shadowing structure can comprise a number of parallel, narrow and deep grooves, while the width and the depth of the grooves are such that, in the layer application process, at least a part of the side walls and/or the bottom of these grooves is hardly covered, if at all, with the first conductive layer.

Such a groove structure can be designed to be such that, in a releasing manner, it can be taken from the mold in which the plastic substrate is formed. In the formation process of the plastic substrate, the shadowing structure is provided without, to that end, one single finishing step being required for the plastic substrate. Basically, the shadowing structure is obtained practically free of charge in the formation process of the plastic substrate when the mold has the right shape.

According to still another elaboration of the invention, layers can be applied with the aid of a printing operation such as, for instance, inkjet printing, silkscreen printing, electrostatic printing techniques and thermal transfer printing. In order to somewhat simplify the printing process, it can be advantageous to design the surface structure of the substrate to be such that, as it were, channels have been provided herein in which the liquids dispensed through the printing process are deposited. The walls of the respective channels form the boundaries of the liquid deposited in the channels with the printing process.

Subsequently, with printing techniques, layer application techniques such as sputtering, CVD and PECVD-techniques, layers and layer patterns can be provided with the aid of which the organic electroluminescent display device is composed. Such layers and layer patterns comprise, for instance, a PDOT- and PPV- layer in the pixel pits or sub-pixel pits, insulating layers for covering the first conductor and conductive layers for forming a number of second conductors.

According to a further elaboration of the invention, optionally, with a curing varnish, an additional relief structure can be applied to the substrate already provided with a number of layers, for forming a relief structure desired for the application of a following layer. For instance, in a simple manner, a number of new channels can be formed in which the liquid, forming the second conductors, can be deposited. This curing varnish can for instance be a UV-curing varnish which is deposited locally with an inkjet printing operation. In such a manner, for instance, also the above-described shadowing structure can be removed by filling the relatively narrow and deep grooves up with UV-curing varnish.

According to an alternative, further elaboration of the invention, after application of at least one layer, the shape of the surface structure can be adapted through a transforming technique, such as, for instance, a local thermal treatment. Such a thermal treatment can, for instance, be

contactlessly, via infrared radiation, or laser irradiation or with a contact treatment. Thus, for instance, the groove-shaped shadowing structures can be melted away.

According to the invention, the substrate described in the opening paragraph is characterized in that it is manufactured from plastic and has a surface structure which forms a boundary for at least for a number of the layers to be applied in the method, the surface structure of plastic substrate being provided with a shadowing structure which is such that with the layer application process, parts of this shadowing structure are hardly covered, if at all, with the respective conductive layer, the shadowing structure being such that the electrical resistance prevailing there is great relative to the resistance in the rest of the conductive layer.

Such a plastic substrate provided with a surface structure can be manufactured in one single operation in an injection molding process. This means that the cost price of the substrate can be particularly low. This in contrast with the substrates from glass used heretofore, on which, with the aid of photochemical techniques, structures have been applied.

According to a further elaboration of the invention, the surface structure can comprise a number of pixel pits or sub-pixel pits. Such pits render the deposition of liquid therein, such as for instance PDOT or PPV, with the aid of an inkjet process simple and more controllable.

Further, the surface structure can comprise a shadowing structure which is such that with a sputtering process, indirect sputtering and/or evaporation, parts of this shadowing structure are not covered with the respective conductive layer, so that the shadowing structure forms insulating tracks in the conductive layer. According to a further elaboration of the invention, the shadowing structure can be formed by a number of parallel narrow and deep grooves, while the width and the depth of the grooves is such that at least a part of the side walls and/or the bottom of these grooves are not covered with a first conductive layer in a sputtering process.

According to still a further elaboration of the invention, in the pixel pits or sub-pixel pits, a structure can be provided which influences the generated light that passes the structure. Such a structure can also be provided at the side of the substrate remote from the pixel pits or sub-pixel pits. For instance, a structure in the form of a Fresnel lens, having a converging or diverging effect on the light passing through the structure, can be considered.

Further, according to a further elaboration of the invention, in the pixel pits or sub-pixel pits, a structure can be provided which is designed for improving the distribution of liquid for forming the layers applied in the pixel pits or sub-pixel pits. It is noted that such structures, improving the distribution of liquid, can also be provided in the channels in which, through printing techniques, liquids are deposited, for a better distribution of the liquid.

According to a further elaboration of the invention, a contact surface enlarging structure can be provided in the pixel pits or sub-pixel pits. Firstly, such a contact surface enlarging structure yields a larger conductive surface so that the electrical resistance across a pixel is reduced. Moreover, a larger electroluminescent surface is created so that a greater light intensity per pixel is obtained. Optionally, the structure improving the distribution of liquid can also be combined with the contact surface enlarging structure. The structure can, for instance, comprise a number of capillary grooves.

The invention also provides an organic electroluminescent display device manufactured while using a method according to any one of claims 1 - 30 starting from a substrate according to any one of claims 31 – 44.

Figs. 1 – 18 show the various steps of building up a first embodiment of a display device according to the invention while the Figures with the uneven Figure numbers show cross-sectional views and the Figures with even Figure numbers show top plan views;

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Figs. 19 – 36 show the various steps of building up a second embodiment of a display device according to the invention, while the Figures with uneven Figure numbers show cross-sectional views and the Figures with even Figure numbers show top plan views;

Fig. 37 shows a top plan view of the substrate, wherein a first structure which has been applied in a pixel pit is shown;

Fig. 38 shows a top plan view of the substrate, wherein a second structure which has been applied in a pixel put is shown;

Fig. 39a shows a substrate with a shadowing structure provided therein; and

Fig. 39b shows in which manner this shadowing structure can be locally removed through a thermal laser operation.

Figs. 1 and 2 show a cross-sectional front view and a top plan view of a part of a plastic substrate 1 not yet provided with layers for manufacturing an organic electroluminescent display device. During the manufacture of the substrate, for instance with the aid of an injection molding operation, the substrate has been provided with a surface structure forming a boundary, at least for a number of the layers to be applied. For instance, pixel pits 2 are clearly visible which are bounded by pixel pit boundaries 3. The surface structure further comprises a shadowing structure 4. In the present exemplary embodiment, the shadowing structure has been designed as, each time, a number of parallel, deep, narrow grooves 4', 4", 4'". Such a shadowing structure is such that a layer to be applied with a layer application process such as, for instance, sputtering, hardly covers, if at all, parts of the shadowing structure.

Figs. 3 and 4 shows the same substrate which is provided with a transparent encapsulation layer 5, such as, for instance, a nitride-oxide-nitride-, or, NON-layer. Also, other transparent layers which are tight to water, oxygen and other undesired substances are among the possibilities. The

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transparent encapsulation layer can, for instance, be applied with a deposition technique such as a PVD-, CVD- or PECVD-process.

Figs. 5 and 6 show the substrate after a first conductive layer 6 has been applied. Such layers can be applied with, for instance, a sputtering process. In the present exemplary embodiment, the first conductive layer is formed by a TCO-layer (transparent conductive oxide). Also, other conductive layers can be applied. It is clearly visible that the deep parts of the grooves 4', 4", 4"' are hardly covered, if at all, with the first conductive layer 6. In this manner therefore, parallel conductive paths are obtained insulated from each other and extending in a first direction. The Figures also clearly show that parts of the first conductors extend in pixel pits or sub-pixel pits 2 of the surface structure of the substrate 1. The first conductive layer can also be a so-called PDOT-layer. However, it is also possible that a hole injecting layer 7, such as, for instance, a PDOT-layer is applied exclusively in the pixel pits or sub-pixel pits 2. With this last-mentioned option, which is represented in Figs. 7 and 8, the layer can for instance be deposited in the pixel pits or sub-pixel pits with a printing operation, such as for instance an inkjet operation. Since the pixel pits or sub-pixel pits 2 are bounded by pixel pit boundaries 3, the risk of the liquid forming the PDOT-layer flowing outside the pixel pits or sub-pixel pits 2 is reduced to a minimum.

Thereupon, in Figs. 9 and 10, it is shown that in the pixel pits or sub-pixel pits 2, further, a light emitting layer 8 is deposited, such as, for instance, a PPV-layer. This layer too can be provided with the aid of, for instance, inkjet printing.

Figs. 11 and 12 show that the shadowing structure 4 and, more in particular, the deep, narrow grooves 4', 4", 4"' are filled up with an insulating covering 9. This covering can for instance be formed by a UV-curing varnish which can be accurately applied with the aid of an inkjet printing operation. Instead thereof, the method represented in Fig. 39b can also be used.

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Then, as shown in Figs. 13 and 14, the entire substrate 1 is covered with a layer of barium 10, whereupon, as shown in Figs. 15 and 16, a second conductive layer 11 is applied such that a number of parallel conductors 12 is provided, extending in a second direction and which are mutually insulated from each other. Parts of the second conductors 12 extend in pixel pits or sub-pixel pits 2 of the surface structure of the substrate 1. In the present exemplary embodiment, the second conductors 12 extend perpendicularly to the first conductors which extend between the parallel shadowing structures 4. The second conductive layer 11 too can be selectively applied with the aid of a printing process, such as for instance an inkjet printing operation.

Finally, Figs. 17 and 18 show that a second encapsulation layer 13 is applied over the entire substrate. This layer too seals off from undesired substances, such as, for instance, water, oxygen and the like.

Figs. 19 and 20 show a second embodiment of a substrate 21. In contrast to the first exemplary embodiment, this substrate has not been provided with a shadowing structure as described hereinabove. Instead thereof, a channel structure 24 with channel boundary 24' is present for a printable first conductive layer. Also, the pixel pits or sub-pixel pits 22 are clearly visible with the pixel pit boundaries 23. Further, a separating structure 25 is already partially present for a printable second conductive layer. This separating structure 25 is still interrupted at the location of the channels 24 in which the first conductive layer 27 is to be printed.

Figs. 21 and 22 show the same substrate which is provided with a transparent encapsulation layer 26, such as, for instance, nitride-oxide-nitride, or NON-layer. Also, other transparent layers which are tight to water, oxygen and other undesired substances are among the possibilities. The transparent encapsulation layer 26 can, for instance, be applied through an evaporation technique such as a CVD- or PECVD-process.

Figs. 23 and 24 show a printed first conductive layer 27. It is clearly visible that the first conductive layer 27 extends in the channel structure 24

intended thereto and in the pixel pits or sub-pixel pits 12. In the present exemplary embodiment, the first conductive layer 27 is formed by a PDOT-layer which has been provided on the desired location with the aid of an inkjet printing operation. The channel structure boundary 24' and the pixel pit boundary 23 ensure that the liquid does not flow outside the desired areas.

Figs. 25 and 26 show that in the pixel pits or sub-pixel pits 22, further, a light emitting layer 28 is deposited, such as, for instance, a PPV-layer. This layer 28 too can be provided with for instance inkjet printing.

In Figs. 27 and 28 it is shown that across the channel structure 24, an insulating covering 29 has been provided. The insulating covering 29 can for instance be formed by a UV-varnish or photoresist varnish.

Figs. 29 and 30 show that the separating structure 25 has also been provided in the channel structure 24 through the provision of a threshold 30 therein. The additional relief structure is therefore provided on the substrate already provided with a number of layers for forming a relief structure desired for applying a following layer. In the present exemplary embodiment, the additional relief structure 30 is provided with the aid of a printing operation, while using a curing varnish, for instance a UV-curing varnish. Thus, channels 31 are formed, extending parallel to each other, while the channel direction is perpendicular to the first direction mentioned in which the first conductors 27 extend.

Figs. 31 and 32 show that, thereupon, the entire substrate is covered with an electron injecting layer 32 such as, for instance, a calcium-, magnesium-, lithium fluoride- or barium-layer.

Subsequently, Figs. 33 and 34 show that the second conductive layer 33 has been provided in the channels 31, for instance with the aid of an inkjet printing operation. The second conductive layer 33 provides a number of parallel conductors, mutually insulated from each other and extending in the second direction, while parts of the second conductors extend in pixel pits or sub-pixel pits 22 of the surface structure of the substrate 21.

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Finally, Figs. 35 and 36 show that after the application of the second conductive layer, an encapsulation layer 34 is applied over substantially the entire surface of the substrate. This layer too seals off from undesired substances such as, for instance, water, oxygen and the like. The layer can comprise, for instance, a Nitride-metal-Nitride layer, a NONON-layer or a NDLCN-layer (nitride diamond like carbon nitride).

Fig. 37 shows a top plan view of a substrate wherein, in the pixel pits or sub-pixel pits, a structure 35 has been provided which influences the generated light passing the structure. In Fig. 37, the structure forms a Fresnel lens 35 which has a converging, diverging or, conversely, paralleling effect. It is noted that such a structure can also extend over several pixels, so that in a part of the eventual display, the issuing light is optically influenced. Such a structure can also be provided on the side of the substrate remote from the pixel pits.

Fig. 38 shows another structure 36 provided in the pixel pits or sub-pixel pits 2, 22, designed to improve the distribution of liquid for forming layers provided in the pixel pits or sub-pixel pits. Preferably, this structure 36 also has a contact surface enlarging effect. This can, for instance, be effected with a structure which is provided with capillary grooves. Such a larger contact surface not only reduces the electrical resistance, it also provides a larger light emitting surface, so that, also, more light is generated.

Figs. 39a shows, in cross section, once more, a substrate 1 with a shadowing structure 4. In Fig. 39b, it is shown how this structure can be melted away locally with the aid of a laser beam or infrared beam directed through a lens 37, which locally heats the shadowing structure 4 such that it melts, so that the shadowing structure 4 disappears.

It is clear that the invention is not limited to the exemplary embodiments described but that various modifications are possible within the framework of the invention as defined in the claims.

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